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Analytical Evaluation of Aluminum Cans Crushing Machine

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ABSTRACT
The increasing presence of non-biodegradable waste materials, such as aluminum cans, in our home surroundings, on our streets and roads, bars, restaurants and hotels has adverse effects on our human existence and environment. Consequently, the paper highlights the design and manufacture of Aluminum Can crushing machine that aimed at reducing or eliminating the presence of used aluminum Cans in our environments. The method of approach involved preparing detail design of the machine parts, selection and purchase of materials locally, fabrication and assembling of the various parts in the mechanical workshops. The fabricated Aluminum crushing machine was then tested and evaluated for effectiveness. The results obtained showed gave required power input of 382W with piston velocity of 0.813m/s. The crushing rate of the machine was approximately 2 Cans/sec, 70% efficient, durable and rigid and able to withstand vibrations, and of self-loading capability. The Aluminum Can Crushing Machine was fabricated, tested and its performance evaluated. The Aluminum crushing machine was observed to be effective, portable and operator friendly requiring minimum human effort to perform the function for which it was designed.

Keywords: Aluminum Cans, Crushing, recycling, environment pollution**.**

I. INTRODUCTION

In our world today a lot of human consumables come in Cans. In Nigeria so many food items are packaged in Cans especially beverages and alcoholic drinks. The disposability of these Cans after using the contents has with time become a major problem to our communities. In some places like households, restaurants, hotels, eateries and so on these empty Cans are mostly stacked into bags which eventually occupied the limited space or are thrown around the immediate environment and streets to constitute nuisance to the society.

One way of reducing the number of Cans littering the streets to recycling used Cans. Aluminum Cans can be recycled into new aluminum Cans or other products. For the former, aluminum Cans recycling is usually preceded by processes such as collecting, transporting, sorting and so on; while for the later, the processes involved would be collecting, crushing, transporting, and so on . According to Buza (2014) recycling is the last stage of reducing, reusing and recycling (3Rs) into raw material for other products. Recycling saves energy and money, as a source of raw materials, prevents environmental pollution, and creates jobs. With the increase of human population and ecosystem empty aluminum Cans today are sources of problem of environmental degradation and depletion of natural resources are likely to cause disease. The existing crushers are heavy ones and these crushers are excessively used for crushing materials at big industries and manufacturing plants for crushing cars, stones, metal components, etc., Moreover, these crushers are hydraulically and pneumatically operated and are feasible if very high amount of crushing forces are required for crushing a material. The operating costs of these crushers are very high as it requires continuous power, continuous maintenance as this involves hydraulic fluid or compressors kits, etc. These type of high end crushers are not necessary for small recycling plants and is not affordable to many people. It requires proper maintenance as the hydraulic fluid needs to be changed constantly on time basis. It also requires skilled labor for operation. (Senthil et. al., 2016).

A Can crusher is one of the most usable machines that can help to reduce the environmental pollution in the world. (Kshirsagar, 2014). Waste management and disposal is a tedious task when it comes to large quantity of Cans which results from huge consumption. With waste management problem is also embedded with the problem of transporting Cans to the recycling plants, which

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requires huge amount time and money. Gogoi et al. (2018) exerted that Can Crushers are widely applied in mechanical and allied industries such as beverage industries and in scrap dealers' shop to crush Cans made of different materials into smaller sizes a process that leads to the reduction in transportation cost and to save space. Therefore, crushing the Cans can help to maintain eco-friendly environment. (Chakule, 2020).

Rajesh et al. (2016) study reported the design and structure analysis of Can crusher. The study discussed processes like design, fabrication and assembling procedures which was the main purpose of the study. The designed Can crusher used mechanical single slider crank mechanism. The designed crusher was observed to be environmental friendly. Nagarajan et al. (2017) fabricated a manually operated Can crushing machine that incorporated a "quick return mechanism" for crushing two Cans separately at the same time by crushing a one Can during piston forward stroke and the other Can at the return stroke of the piston. The incorporated "quick return mechanism", which is an inversion of slider-crank mechanism, is to converts rotary motion into reciprocating motion. The designed crusher was observed to be environmental friendly. Gogoi et al. (2018) fabricated a Can crusher using single slider-crank mechanism that can reduce Can size by at least 70%. Two Can crushers were constructed. One is manually operated and the other a manual crusher model upgraded to an electrically operated one. Efficiencies and construction costs comparison was carried between the two Can Crushers. The electrically operated was observed to have higher efficiency and cost. Kumar et al. (2017) designed Can crushing machine that uses slider-crank mechanism with two sides crushing ability. The designed Can crusher is based on existing vertical crushing machines. A lot of tests were carried out to validate the crushing machine and its components. Results showed the machine and its elemental parts to function well. Qais et al. (2015) designed and constructed a Can crusher that is automated and uses mechanical single slider and microcontroller and sensor. The designed Can crusher was observed to function well. Devmane and Aloni (2017) design was mainly carried out in order to understand the fundamental knowledge of designing, mechanism and fabrication. The designed model has wide usability for crushing Cans and bottles. The designed Can crusher functions by holding a Can between two parallel solid surfaces and apply force on the Can by single slide mechanism that is driven by electric motor. Thus, by bringing the two solid surfaces together, the Can is eventually crushed. The Can crusher is designed aid recycling, easily maintained and eco-friendly also. Elfasakhany et al. (2012) Can crusher was constructed based on knowledge in horizontal and vertical crushing designs. The designed Can crushing machine is made up of hardwares (like mechanical structure, servomotor, light sensor, arduino microcontroller, and pneumatic system) and software (such as maestro for operating and controlling different system components). Testing and validation of the machine indicated that the crusher operated well. Khanapure et al. (2015) designed and fabricated Dual Stroke Aluminum Can Crusher. The special feature of the design is the automatic removal of crushed Cans from the crushing point and the automatic feeding of Cans to be crushed.

The above survey on Can crushing machine shows that a lot of studies and designs have been carried out over the years in other countries.

In this project aluminum Can crushing machine is designed and constructed with the aim of reducing the volume of aluminum Can by approximately seventy percent (70%) before transporting for recycling. Reducing the size of the Cans before transportation will greatly reduce the cost of transportation and ensure ease of handling.

II. METHODOLOGY

2.1 Single Slider-crank Mechanism

Slider-crank mechanism is consists of components (links) that are systematically connected to transmit motion. Slider-crank mechanism is widely used in internal combustion engines, Can crushers, etc.

Single slider-crank mechanism is shown in Fig. 2.1, where A is the slider, AB represents the connecting rod and CO represents the crank.

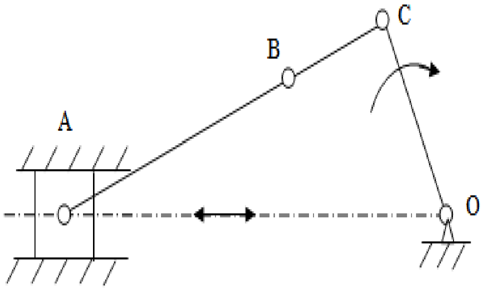

Fig. 2.1: single slider-crank mechanism

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2.2 Analytical Method: kinematic of Machine Parts

In the following sections, mathematical expressions in Khurmi and Gupta (2009) are used to analyze the slider, crank and connecting rod displacements, velocities, angular velocities and angular accelerations.

Design machine parameters:
Mass of slider m_s = 22kg
Slider force F_p = 220N
Angular velocity $\omega = n_b$ = 80rpm (8.38rad/s)
Length of connecting rod, L_{cr} = 0.305m
Crank length, r = 0.18m
θ = Crank angle.
ϕ = angle of inclination of connecting rod to stroke axis.
n = ratio of connecting rod length to crank length (L_{cr}/r) = 0.305/0.18 =1.694m.
Slider

III. RESULTS AND DISCUSSION

3.1 Slider

3.1.1 Slider position

$x_s(\theta) = r[(1 - \cos\theta) + \sin^2\theta/2n] = r[(1 - \cos\theta) + (1 - \cos2\theta)/2n]$

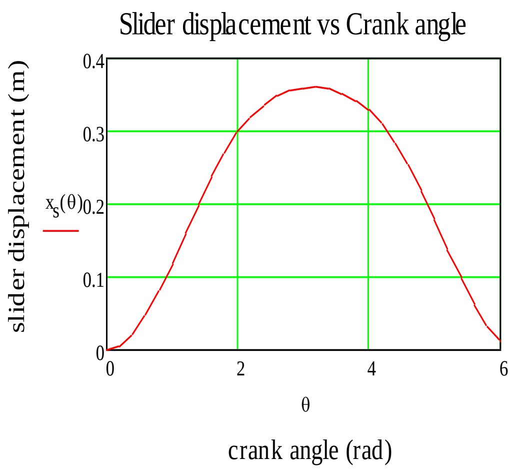

Fig. 9: slider displacement vs. crank angle

3.1.2 Slider velocity

$v_s(\theta) = \omega.r.[\sin\theta + \sin 2\theta/ 2n]$

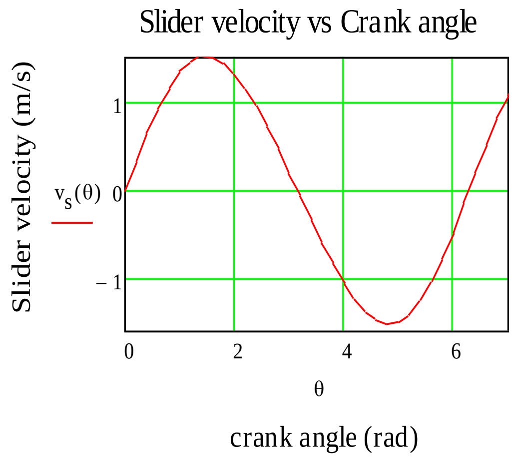

Fig. 10: slider velocity vs. crank angle

3.1.3 Slider acceleration

$a_s(\theta) = \omega^2 r [\cos\theta + \cos2\theta/n]$

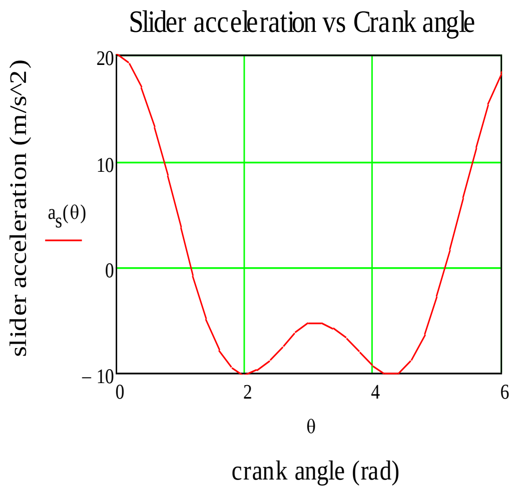

Fig. 11: slider acceleration vs. crank angle

3.1.4 Slider accelerating force

$F_a = m_s \times \omega^2 r [\cos\theta + \cos 2\theta/n]$

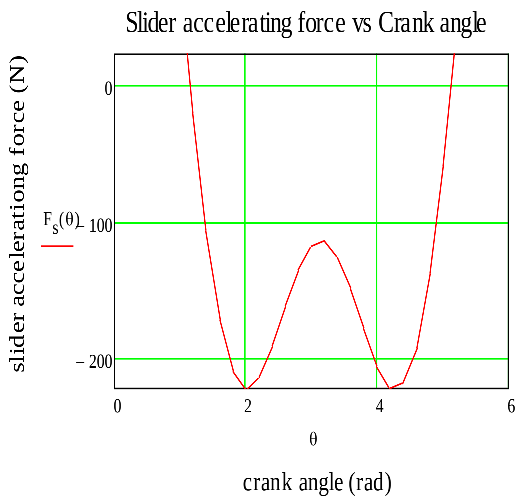

Fig. 12: slider accelerating force vs. crank angle

3.2 Crank

3.2.1 Crank angular velocity

$\omega_{c,x}(\theta) = \omega r.\cos(\theta)$

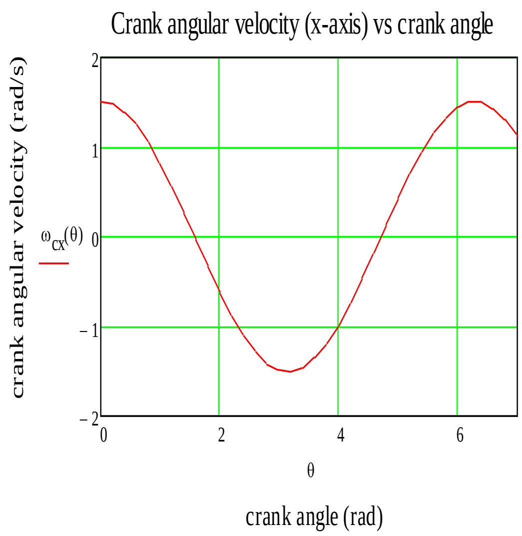

Fig. 13: crank angular (x) velocity vs. crank angle

$\omega_{c,y}(\theta) = -\ \omega r.\sin(\theta)$

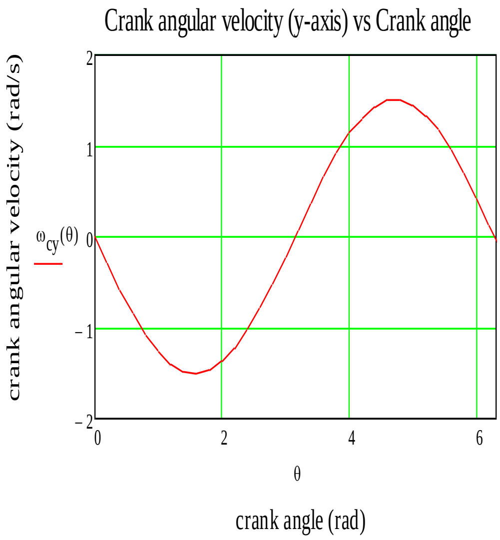

Fig. 14: crank angular (y) velocity vs. crank angle

3.2.2 Crank effort

$E_c = F_p \times r[\sin\theta + \sin 2\theta/2(n^2 - \sin^2\theta)^{½}] = F_p \times r[\sin\theta + \sin 2\theta/2(n^2 - (1 - \cos 2\theta)^{½}]$

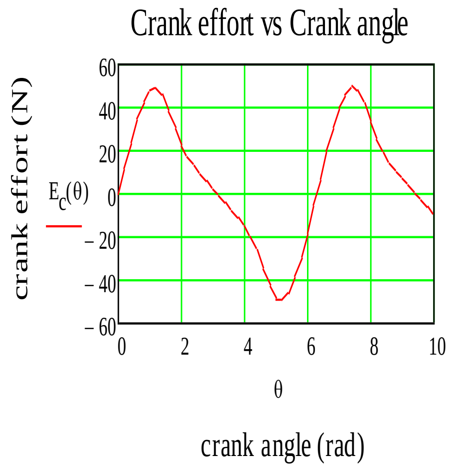

Fig. 15: crank effort vs. crank angle

3.3 Connecting rod

3.3.1 Connecting rod displacements

$\phi_{cr,x}(\theta) = \sin^{-1}[\ r/L_{cr} \sin\theta]$

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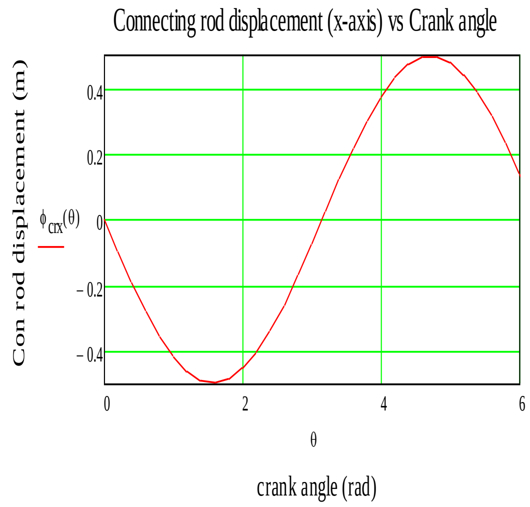

Fig. 16: connecting rod displacement (x) vs. Crank Angle

$\phi_{cr,y}(\theta) = \cos^{-1}[\, r/L_{cr} \cos\theta]$

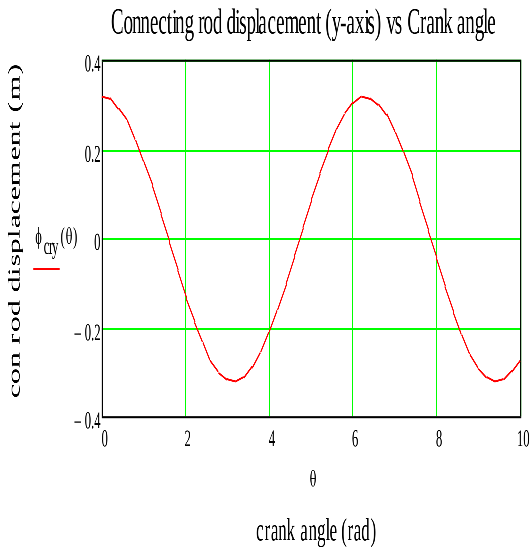

Fig. 17: connecting rod displacement (y) vs. Crank Angle

3.3.2 Connecting rod angular velocity

$\omega_{cr}(\theta) = \omega.\cos\theta/(n^2 - \sin^2\theta)^{½} = \omega.\cos\theta/[n^2 - (1 - \cos 2\theta)]^{½}$

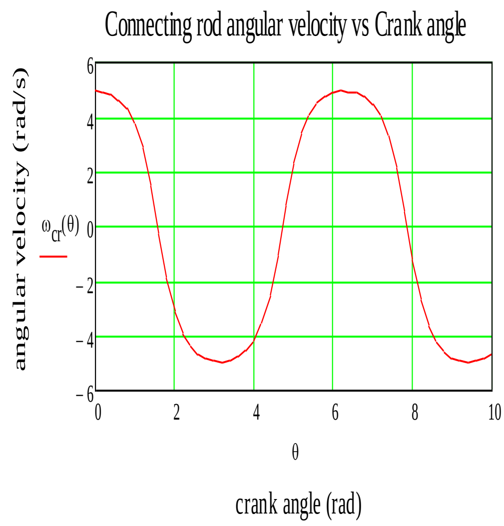

Fig. 18: connecting rod angular velocity vs. crank angle

3.3.3 Connecting rod angular acceleration

$a_{cr}(\theta) = -\omega^2.\sin\theta\ (n^2 - 1)/(n^2 - \sin^2\theta)^{3/2} = -\omega^2.\sin\theta\ (n^2 - 1)/[n^2 - (1 - \cos 2\theta)]^{3/2}$

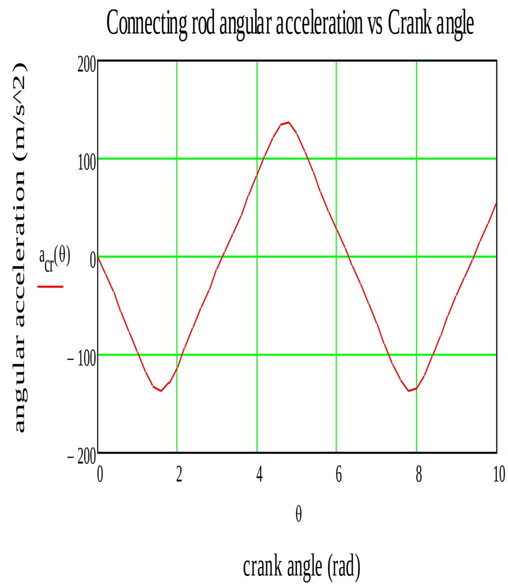

Fig. 19: connecting rod angular acceleration vs. crank angle

3.3.4 Connecting rod force

$F_{cr}(\theta) = F_p/(1 - \sin^2\theta/\,n^2)^{½} = F_p/[1 - (1 - \cos 2\theta)/\,n^2]^{½}$

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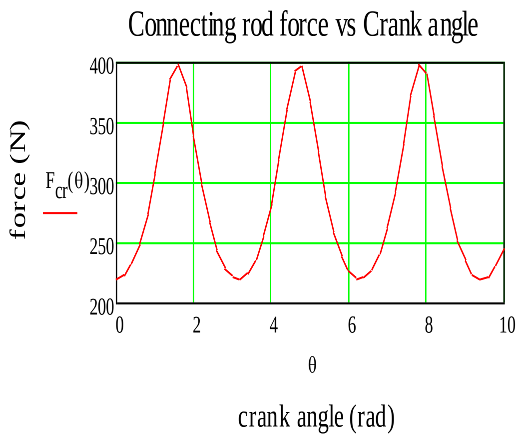

Fig. 20: connecting rod force vs. crank angle

For the slider displacement, Fig. 9 shows that the slider displacement with the crank angle is sinusoidal, that it takes 360^o to complete a to-and-fro motion.

Fig 10 shows slider velocity versus crank angle. It is indicated in Fig. 10 that as the slider start from 0^o, the velocity increasing with crank angle to 90^o before decreasing to -270^o to start increasing again. In Fig. 10 it can be seen that the velocity curve is smooth, which is an indication of absence vibration. Fig. 11 shows the variation of slider acceleration against crank angle. The indication that the crushing machine slider acceleration is purely sinusoidal implies the convergence with theoretical expression for slider acceleration.

In Fig. 12 it is revealed that the slider accelerating force application is sinusoidal in application as the slider acceleration. Crank angular velocity (x-axis) versus crank angle is shown in Fig. 13 in which the crank angular velocity is seen to decrease from 1.5rad/s^2 to -1.5rad/s^2 and then increases to 1.5rad/s^2 to complete a cycle. On the other hand, in Fig 14, the crank angular velocity (y-axis) versus crank angle in shows the crank angular velocity to decrease from 0rad/s^2 to -1.5rad/s^2 and then increases to 1.5rad/s^2 to complete a cycle. Fig. 15 shows crank effort versus crank angle in which the crank effort decreases from 0 N to approximately -50N and then increases to 50N to complete a cycle. In Fig. 16, the connecting rod displacement (x-axis) is plotted against the crank angle of rotation. For the connecting rod displacement, Fig. 16 shows that the connecting rod displacement is sinusoidal and takes 360^o to complete a cycle. On the other hand, in Fig 17, the connecting rod displacement (y-axis) versus crank angle in shows decrease from 0.3rad/s to -0.3rad/s and then increases to 0.3rad/s to complete a cycle. Fig. 18 shows a plot of connecting rod angular velocity versus crank angle. The angular velocity is seen to increase from 5rad/s^2 to -5rad/s^2 and then up to 5rad/s^2 to complete 1 cycle of crushing a Can. Connecting rod angular acceleration versus crank angle is shown in Fig. 19 in which the crank angular velocity is seen to decrease from 0rad/s^2 to -150rad/s^2 and then increases to 1.5rad/s^2 to complete a cycle. Fig. 20 shows connecting rod force versus crank angle in which the connecting rod force decreases from 220N to approximately 400N and then decreases to 220N to complete every cycle.

IV. CONCLUSION

The Aluminum Can Crushing Machine was designed and fabricated, and then tested to evaluate its performance. The crushing machine was observed to be effective. Essentially, the Aluminum Can crushing machine portable and operator friendly; minimum human effort is only required for loading and offloading of Cans. Finally, the machine is found to be able to perform the function for which it was designed.

REFERENCES

[1]. Buza, S. A., Buza, K. A. and Pllana, K. (2014). Can Crusher Design In Response To Environmental Concerns. Journal of Trends in the Development of Machinery and Associated Technology, Vol. 18, No. 1, p.p. 179-182

[2]. Chakule, R., Patil, S. and Talmale, P. (2020). Design and Development of Can Crushing Machine. Asian Journal of Engineering and Applied Technology, Vol. 9 No. 1, pp.25-28

[3]. Devmane, S. and Aloni, S.N. (2017). Design And Fabrication Of Plastic Bottle And Can Crusher For Recycling Purpose. International Journal of Mechanical Engineering. Volume 5, Issue 6, pp 1 – 3

[4]. Elfasakhany, A., Marquez, J., Rezola, E.Y. and Benitez, J. (2012). Design and Development Of An Economic Autonomous Beverage Cans Crusher. International Journal of Mechanical Engineering and Technology, Volume 3, Issue 3, pp 107 - 122

[5]. Gogoi, B., Boruah, C., Kurmi, P., Bhuyan, J. And Begum, C.A. (2018). Fabrication Of An Aluminium Can Crusher Machine. A Project Report : Jorhat Engineering College, Jorhat.

[6]. Kshirsagar, V. N., Choudhary, S. K. and Ninawe, A. P. (2014). An Automatic CAN or Plastic Bottle Crusher Machine - A

Review. International Journal for Scientific Research & Development| Vol. 2, Issue 02, pp 66 – 68

[7]. Kumar, D.V., Rathish, R., Balakrishnan, N., Dineshkumar, D., Devaraj, V., Aravinthan, A. and Anbarasan, G. (2017). Design And Fabrication Of The Double Acting Can Crushing Machine. International Journal of Novel Research and Development , Volume 2, Issue 4, pp 86 – 90.

[8]. Khanapure, L.R., Patil, V. S., Madhawai , D. A., Navale, A.L., Dokfode, A.B., and Bhane, A. B. (2015) The Dual Stroke Can Crusher. International Journal of Recent Development in Engineering and Technology, Volume 4, Issue 4, pp 17 -21

[9]. Khurmi, R. S. and J. K. Gupta (2009). Theory of Machines 14th ed. New Delhi: Eurasia Publishing House (PVT) Ltd., pp 369 – 372 and 523 – 531

[10]. Nagarajan, N., Srinivasan, S. and Balthilak, A. (2017). Design And Fabrication Of Can Crushing Machine. International Journal of Current Engineering And Scientific Research, VOLUME-4, ISSUE-7, p 6 – 12

[11]. Qais, S., Saif, S., Jafar, S. and Nadeem, S. (2015). Fully Automatic Can Crusher. International Journal of Mechanical and Industrial Technology, Vol. 2, Issue 2, pp: 155-159

[12]. Rajesh, R., Selvadurai, S., Sivakumar, S., Vino, M., and Veeramuthu, R. (2016). Design and Fabrication of Can Crusher. International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 5, Special Issue 8, p 105 - 110

[13]. Senthil, K.N., Naveen, P.D., Nirmal, K.R. and Premvishnu,R.S. (2016). Design Of Mechanical Crushing Machine. International Research Journal of Engineering and Technology, Volume: 03 Issue: 01, pp921 - 926

[14]. Sontakke, K., Yadav, H., Wakchaure, C., Samere, P. and Agte, K.P. (2016). Design and Fabrication of Automatic Can Crusher. Imperial Journal of Interdisciplinary Research,Vol-2, Issue-7, pp 210 – 223